PHYSIOLOGY

SHEET NO. 5

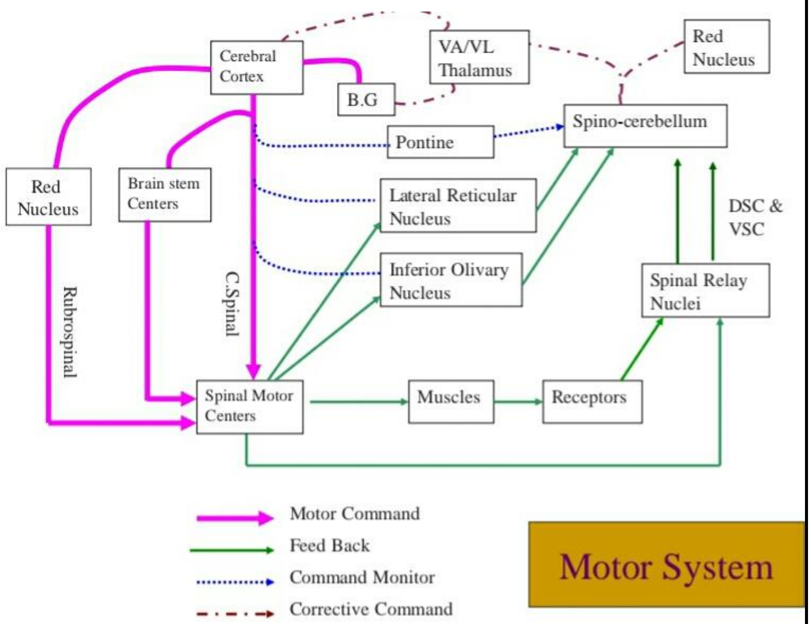
WRITER : Doctor 019

CORRECTOR : Malek absia

DOCTOR : Faisal Mohammad

The Cerebellum

We will start by a general overview about the motor control:

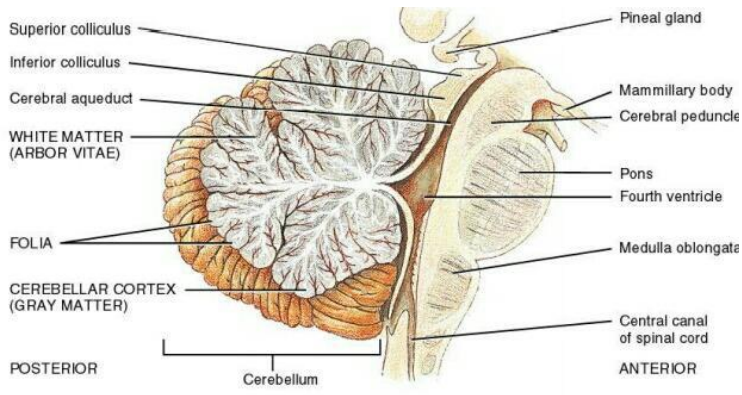


- Starts from motor command that is initiated in the cerebral cortex [corticospinal tract], or other descending tracts from the brain stem, or red nucleus.
- The command monitor function:
    1) Corticopontocerebellar tract comes from the cerebral cortex, through pons to the cerebellum, a copy of the command that comes from the cortex to the spinal cord will pass through this tract to the cerebellum [the cerebellum will know what is intended to be done by the cortex]
    2) Corticoreticulocerebellar tract, also related to feedback transmission.
    3) Olivocerebellar tract: from inferior olivary nucleus, also related to feedback transmission.
- The cerebellum receives feedback from the muscle (muscle spindle and Golgi tendon organ). Remember stretch and tendon reflexes, we have **motor fibers** in the spinal cord that go to the muscle and do the reflex, and other **diverging fibers** that goes to the brain through the ventral & dorsal spinocerebellar tracts to tell the cerebellum about the actual movement.
    - Feedback input is about what is occurring in the muscle in terms of length (through muscle spindle), or tension (Golgi tendon), or around the joint (large tactile receptors). And, about the rate of change in tension, so that, the cerebellum will be able to predict the position of the body ahead of time.
- The cerebellum now has received input about the intended position, and the actual position, so that, it can compare both inputs to determine whether they meet or not.
    - If both inputs meet, the cerebellum will send this information to the cortex to tell the cortex that everything is fine [from the cerebellum to the ventroanterior & ventrolateral parts of the thalamus to the cortex].
    - The cortex never sends exact impulse to the muscle, it either sends more than intended or less than intended, so there must be correction, this

correction comes from the cerebellum to the cortex through the thalamus, so the second impulse coming from the cortex will be corrected impulse, but also it will not be the exact intended impulse, rather, it will be more or less, then more or less than intended.. until it reaches the intended position.

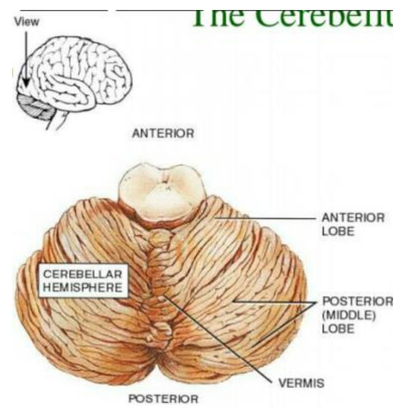
- That is why the cerebral cortical movement is called pendular movement, which means that muscle movement will be up & down like dancing (tremor) unless the corrective command comes from the cerebellum.

The cerebellum (little brain)



(c) Midsagittal section of cerebellum and brain stem

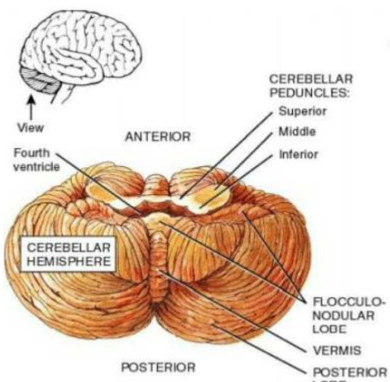
- The cerebellum was previously thought to have no function, and its function was known by destructing it, and observing the abnormality that will occur.
- The function of the cerebellum:
  1. *Coordinating* muscle activity.
  2. *Sequences* the motor activity.
  3. *Monitors* and makes corrective adjustments in the activities initiated by other parts of the brain.
  4. *Compares* the actual motor movement, and the intended movement and makes corrective changes which will be sent to the cortex through the thalamus.



(a) Superior view

The Anatomy of the cerebellum

- Located in the posterior cranial fossa, dorsal to the brain stem & the 4th ventricle.
- The cerebellum has 2 major lobes:
  - Anterior lobe (Paleocerebellum).
  - Posterior lobe (Neocerebellum).
- We have also a lobe called Flocculonodular lobe, it receives input from the vestibular nuclei & ocular motor nerves to adjust ocular muscle movement & prevent nystagmus.
- The middle structure is called the vermis.
- The vermis & flocculonodular lobe are called Archicerebellum (the most primitive part).



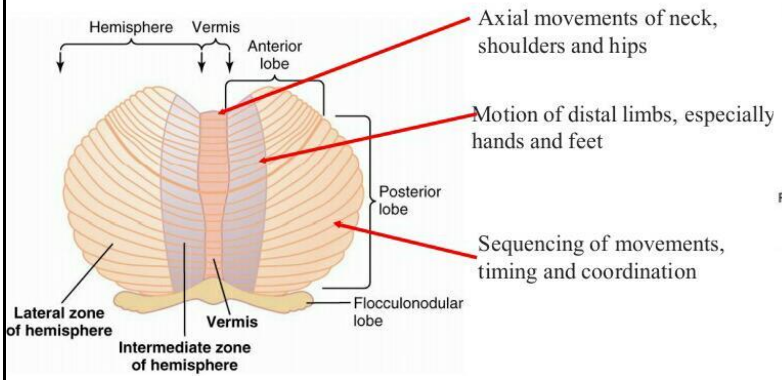
(b) Inferior view

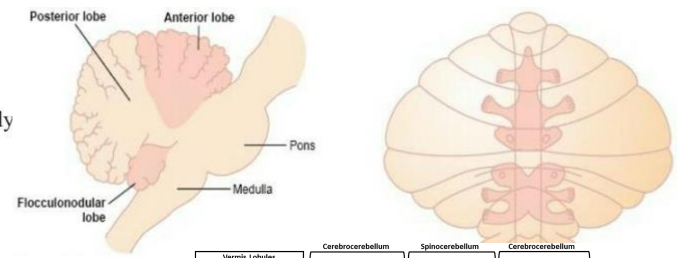
The floculonodular lobe called Vestibulocerebellar zone

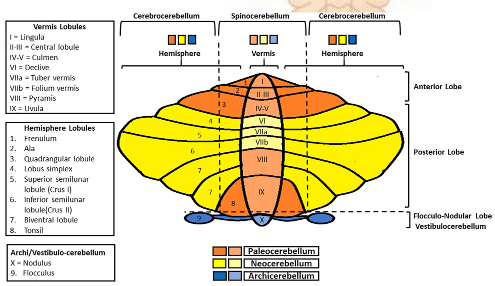
The vermis &intermediate zone Called spinocerebellar zone

The functional organization of the cerebellum

- It can be divided into longitudinal parts where we have 2 representations of our body.
- The midline structure (vermis/ .
  represents the axial muscles and large extensors (hips & shoulder girdles). This area of the cerebellum is responsible for balance & equilibrium.
- The intermediate zone (spinocerebellar zone): located lateral to the vermis & flocculonodular lobe, represents the distal flexor muscles (especially hands & feet).
- The lateral zone (corticocerebellar): does not represent any part of our body which means that it does not receive feedback from the muscles. This area is concerned with planning, timing & coordination of sequential movement through sending & receiving fibers to & from the cortex.



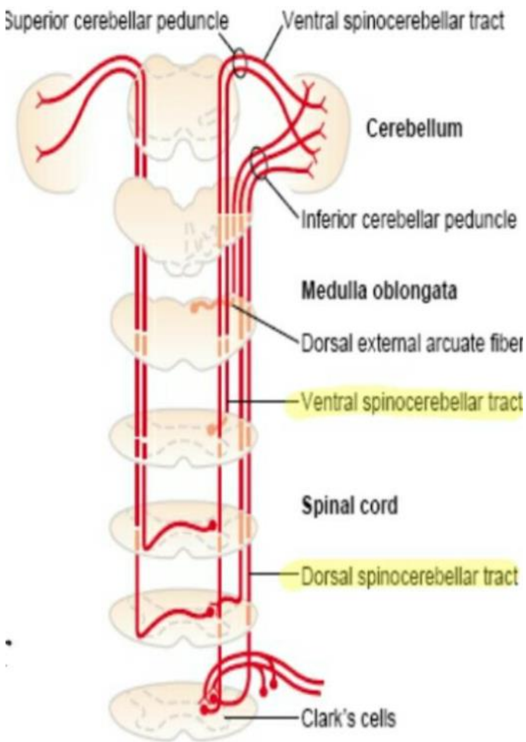




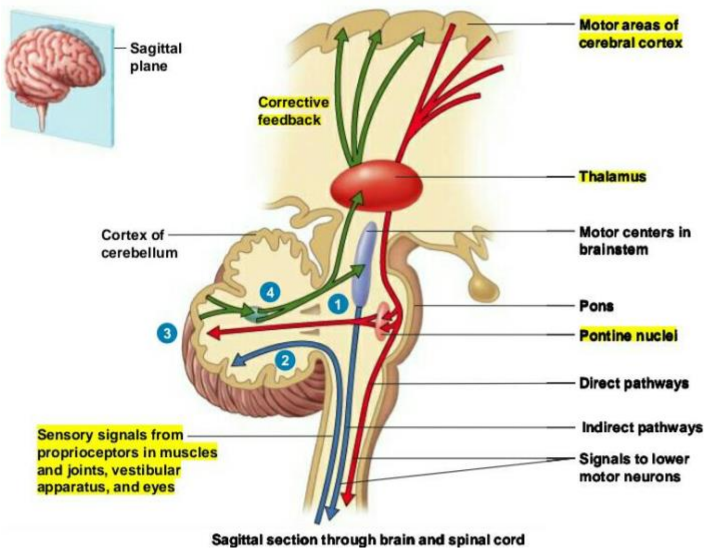
Afferent pathways to the cerebellum

- Afferents from the brain: pons, reticular formation, vestibular nuclei or inferior olivary nucleus.
  - Corticopontocerebellar pathway: Starts from the motor, premotor, somatosensory cortex, and pontine nuclei to the cerebellum, projects mostly to the *lateral hemisphere.*
  - Reticulocerebellar & vestibulocerebellar tracts represents the axial & antigravity muscles, so fiber from these tracts will go to the vermis & flocculonodular lobe.
  - Olivocerebellar tract: from the inferior olive, the olive can act as a cerebellum by itself.
  - These tracts convey the intention [command monitor].

- Afferents from the periphery:
    - Dorsal spinocerebellar tract: uncrossed (ipsilateral) tract that transmits feedback mostly from muscle spindle but also from Golgi tendon organs, large tactile, and joint receptors. It conveys information about the momentary status of muscle contraction, tension, position & forces acting on the body surface.
        - ✓ Muscle spindle: feedback about the length [static], and the rate of change of length [dynamic] for prediction of position.
        - ✓ Golgi tendon: feedback about change in tension and length.
        - ✓ Large tactile receptors: feedback about muscle position (proprioceptors).

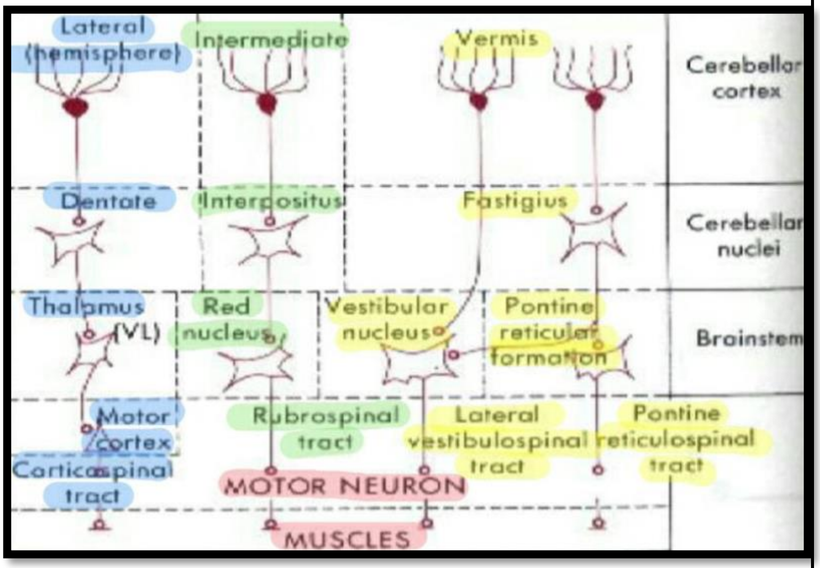


    - Ventral spinocerebellar tract: a bilateral tract that takes its origin from alpha motor neurons in the anterior horn (not from receptors).
        - ✓ Alpha motor neurons receive many synapses (from corticospinal, rubrospinal, vestibulospinal & reticulospinal tracts).
        - ✓ Each of these fibers produces certain impulse to alpha motor neuron (EPSP, IPSP), and eventually, these potentials will summate producing the *grand potential* that will cause excitation or inhibition to alpha motor neuron.
        - ✓ The ventral spinocerebellar tracts take a copy (efference copy) of this grand potential from the final common pathway before it reaches the muscle and sends it to the cerebellum.
- Now, the cerebellum has received input about the intention, the actual movement, and the impulse before it reaches the muscle. Multiple inputs allow correction if an abnormal change occurs in one of the signals.
- Note on the figure: the afferent fibers (feedback from the periphery, and corticopontocerebellar pathway), as well as efferent fibers from the cerebellum back to brain stem areas or to the thalamus then to the cortex (corrective command).



Efferent pathways from the cerebellum

- All efferent pathways go out from deep cerebellar nuclei: 3 nuclei; one for each zone of the cerebellum.
  - Vermis: has *fastigial nucleus*. Since the vermis is concerned with the axial & antigravity muscles, it is usually related to the vestibular system & reticular formation because these structures are -also- related to axial & extensor muscles that are related to equilibrium & position.
    - ✓ Efferent fibers go from the vermis to fastigial nucleus to the reticular formation [Fastigioreticular tract], or to vestibular nuclei [Fastigiovestibular tract], and some fibers go from the cerebellar cortex (vermis) *directly* to the lateral vestibular nuclei (so the lateral vestibular nuclei may work functionally as deep cerebellar nuclei).



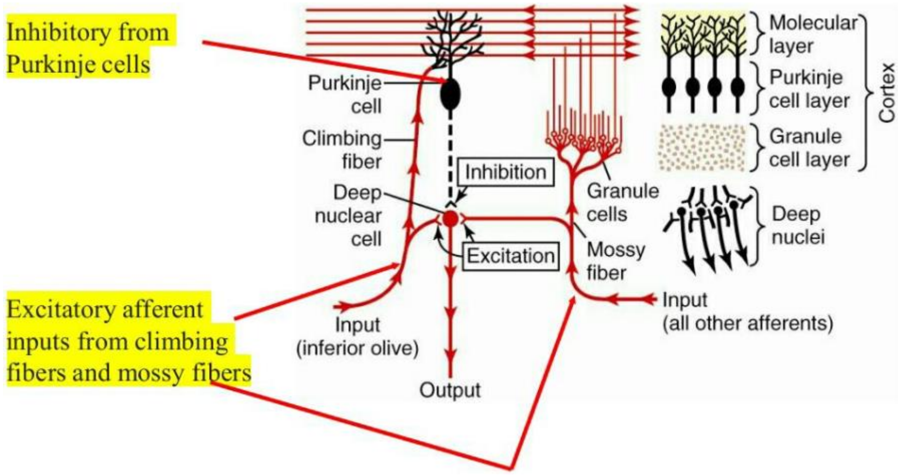
  - Intermediate zone: has *Interpositus nucleus (Globose+Emboliform)*. Fibers go from interpositus nucleus to the red nucleus [interpositorubral tract], to the spinal cord [rubrospinal tract].
    It is concerned with fine voluntary movement of the distal muscles.
  - Lateral zone: has *Dentate nucleus*, related to the thalamus (VA and VL) & the cortex [Dentatothalamocortical tract], then from the cortex to the spinal cord [corticospinal tract]. It coordinates agonist & antagonist muscle contraction, planning, and coordination of the movements.
    Dentate nucleus has cognitive function due to its communication with association areas of the cerebral cortex.

Neuronal Organization of the cerebellar cortex

- The cerebellar cortex is organized in 3 cell layers: molecular layer, Purkinje cell layer and granular cell layer.

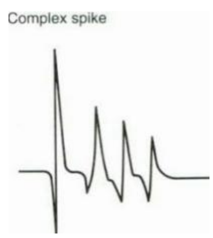
- Output from the cerebellum comes from a deep nuclear cell layer located below these layers of cortex.
- 500 - 1000 granule cells for every Purkinje cell, anywhere from 80,000 to 200,000 parallel fibers synapse with each Purkinje cell.
- The molecular layer contains the parallel fibers; granular cells send axons to the molecular layer where they divide and go a few mm in opposite directions to become parallel fibers.
- The afferent fibers: climbing fibers (coming from the inferior olive), and Mossy fibers (all other afferent fibers).

Neuronal Circuit of the cerebellum



1) Afferent fibers excite deep cerebellar nucleus.
2) Output from deep cerebellar nucleus will descend right away as excitation.
3) Mossy fibers synapse with granular cells, the axons of granular cells (parallel fibers) synapses with Purkinje fibers.
4) Climbing fibers synapse directly with Purkinje fibers [without granular cell intermediate].
5) Purkinje fibers now are stimulated, these fibers are inhibitory neurons, they will synapse with the deep nuclear cells.
6) Inhibitory output from deep cerebellar nucleus will descend to the muscle.

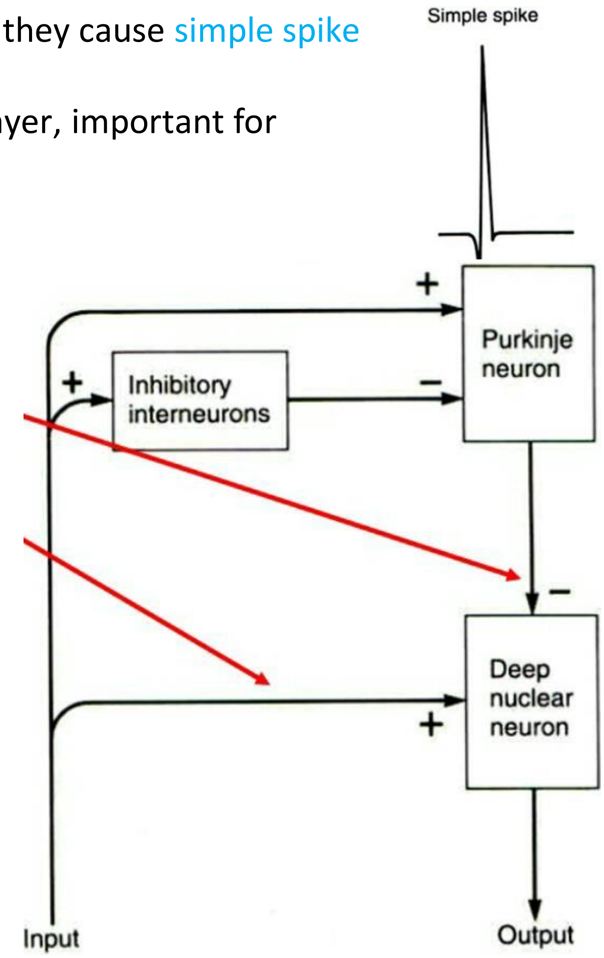
- So, the deep cerebellar nuclei will send excitatory, then, inhibitory output, so the movement will be like a sequence, this is what we need in some movements like writing or typing.
- These components of the circuit are the functional unit of the cerebellum, the functional unit is always concerned with Purkinje fibers (the fibers that synapse with one Purkinje fiber are considered a unit).
- **Climbing fibers** send branches to the deep nuclear cells before they make extensive connections with the dendrites of the Purkinje cell. They cause complex spike output to be produced from Purkinje cell.



- Complex potential contains too many spikes, these spikes are important for learning from previous experiences [to learn how to perform certain movement for a particular task].

- **Mossy fibers** terminate in granular cell layer, they cause simple spike (not complex spikes).
- **Lateral inhibitory cells** are in the molecular layer, important for sharpening the impulse.

Deep nuclear cell activity



- Deep nuclear cell at first receives an excitatory input from both the climbing fibers and mossy fibers.
- Few milliseconds later, this is followed by an inhibitory signal from the Purkinje cells.
- Normally the balance is in favor of excitation.
- Direct motor pathway via corticospinal tract is enhanced by cerebellum by additional *signals to the tract* or by *signals through the thalamus back to the cortex.*
- How does this pattern of signals affect the motor activity?

⇒At the beginning of motion there are excitatory signals sent into the motor pathways by deep nuclear cells to enhance movement, followed by inhibitory signals milliseconds later.

⇒Provides a damping function to stop movement from overshooting its mark [more than the intended movement].

⇒Resembles a delay-line type of electronic circuit for negative feedback.

- Turn-On/Turn-Off function:

⇒At the beginning of motion: cerebellum contributes to the rapid turn-on signals for agonist muscles and turn-off of antagonist.

⇒At the end of motion: it does the opposite sequence of signals, so the agonist muscle will be inhibited, and the antagonist muscle will be excited.

Correction of motor errors

- Precise motor movements must be learned, and the cerebellum is very important to learning skilled motor movement like writing, speaking and car driving.
- When a young child starts writing, he will hold the pen tightly and may perforate the paper, this is because his movement now is cortical movement (coarse,

pendular) not skilled movement, afterwards, the cerebellum will learn how to produce the proper movement, and writing becomes smooth.

- How does learning occur?

⇒Climbing fiber's input adjusts the sensitivity of the Purkinje cells to stimulation by parallel fibers.

⇒This changes the long-term sensitivity of the Purkinje cell to mossy fiber input (i.e., from muscle spindle, Golgi tendon, proprioceptor).

⇒This adjusts the feedback control of muscle movement, and by time, the movement becomes finer.

⇒Learning usually causes anatomical changes, but it may also cause functional changes (membrane proteins, neurotransmitters).

- The role of inferior olivary complex: It receives input from the *corticospinal tract* and *motor centers of the brain stem,* and *sensory information from muscles and surrounding tissue* (from large tactile receptors) detailing the movement that occurs.
- Inferior olivary complex can act as a cerebellum by itself, it compares intent with actual function, if a mismatch occurs, output to cerebellum through climbing fibers is altered to correct mismatch (usually there is a mismatch), correction output will go to the thalamus then to the cortex, the cortex will produce a corrected command.